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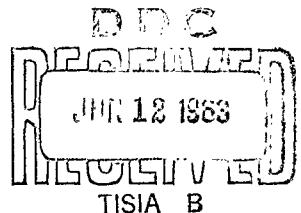
Report No. 8926-157

Material - Magnesium - Aluminum - Zinc -  
Sacrificial Anode

Evaluations in Presence of Sea Water and Clad  
7075-T6 Aluminum Alloy

A. F. Hooper, R. H. Whidden, W. M. Sutherland

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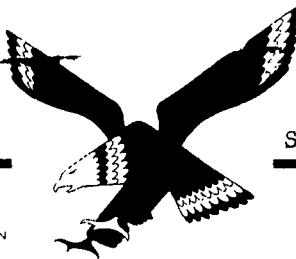
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Evaluations in Presence of Sea Water and Clad  
7075-T6 Aluminum Alloy

Abstract:

Bi-metallic cells consisting of FS-1H magnesium alloy, commercially pure zinc or XA605 aluminum alloy and clad 7075-T6 aluminum alloy were prepared with anode-cathode area ratios of 1:1 and 1:2 and immersed in sea water for measurements of current density versus time and observations of corrosion damage. The FS-1H magnesium alloy anodes corroded severely themselves and did not prevent pitting of clad 7075-T6 aluminum alloy. The commercially pure zinc and XA605 aluminum alloy anodes corroded slightly and prevented corrosion of the clad 7075-T6 aluminum alloy. Current densities over a 24 hour period are reported.

Reference: Hooper, A. F., Whidden, R. H., Sutherland, W. M.,  
"Sacrificial Anodes," General Dynamics/Convair  
Report MP 56-34, San Diego, California, 2 May 1957.  
(Reference attached).



**CONVAIR**  
A DIVISION OF GENERAL DYNAMICS CORPORATION  
**SAN DIEGO**

## STRUCTURES-MATERIALS LABORATORIES

REPORT 56-34

DATE 5-2-57

MODEL MRS 56-183

**TITLE**

REPORT NO. 56-34

## SACRIFICIAL ANODES

MRS 56-183

PREPARED BY

A. F. Hooper

## GROUP MATERIALS & PROCESSES

CHECKED BY

R. H. Whipple

**REFERENCE** \_\_\_\_\_

CHECKED BY

— 1 —

APPROVED BY G. V. Stroh

NO. 65 PAGES 6 12

NO. OF DIAGRAMS 9

## REVISIONS

ANALYSIS

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PAGE 1  
REPORT NO. 56-34  
MODEL MRS 56-183  
DATE 5-2-57

REPORT NO. 56-34  
SACRIFICIAL ANODES

OBJECT:

To evaluate the use of sacrificial anodes for cathodic protection of aluminum alloys in sea water.

CONCLUSION:

FS-1H magnesium alloy was unsuccessful as a sacrificial anode, while commercially pure zinc and XA605 aluminum alloy were successful in cathodically protecting clad 7075-T6 aluminum alloy in a sea water electrolyte.

TEST MATERIALS:

Several bi-metallic cells were tested using FS-1H magnesium alloy, commercially pure zinc and XA605 aluminum alloy as sacrificial anodes in combination with a clad 7075-T6 aluminum alloy cathode. The tests were conducted in a sea water electrolyte. The metal electrodes were 3 x 7 inches in area, varying in thickness from .040 to .064 inches. Each electrode was cleaned with methyl ethyl ketone and then masked with CVAC # Chem 17 leaving the desired test area unmasked. Two tests were conducted on each bimetallic cell by varying the anode-cathode ratios. The anode-cathode ratios tested were 1:1 and 1:2.

The sea water electrolyte was procured below the surface of the water approximately 4 to 5 miles south of the entrance to San Diego Harbor. The 5-gallon glass containers for the sea water had previously been used for the storage of sea water. Each container was rinsed several times with sea water prior to collecting the test electrolyte.

TEST EQUIPMENT:

The test equipment was set-up as shown in Figures 1 & 2. The equipment used in this test is listed below:

1. Precision Scientific Co., thermostatic bath unit, Cat. No. 62696.

2. Leeds and Northrup pH-millivolt meter, ranges of 0-700, 0-1400 and 0-2800 millivolts, Model No. L & N #7664-AI modified.

3. Two N/10 silver-silver chloride reference electrodes with salt bridges (Method of preparation may be found in Report No. 9195-1).

4. Microampere recorder - Modified Speedomax, Type G Recorder, Model S 60,000 series, ranges 0-100, 0-500 and 0-1000 microamperes.

5. Miscellaneous switches and leads.

ANALYSIS

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PAGE<sup>2</sup>

REPORT NO. 56-34

MODEL MRS 56-183

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TEST PROCEDURE:

The sea water electrolyte was placed in a two-quart battery jar and immersed in a thermostatic bath operated at  $77 \pm 0.5^{\circ}\text{F}$ . The two metal electrodes of the bi-metallic cell to be tested were mounted in a bracket at distance of 3 inches apart with the anode-cathode areas facing each other. The tips of the salt bridges from the reference electrodes were placed at a distance of 1/2 an inch from each metal electrode surface.

The circuit diagram, Figure 1, shows the component parts of the measuring circuit. The anode, cathode, IR drop and total cell potentials were recorded at several intervals during the test.

The current flow of the galvanic cell was recorded on the speedomax microampere recorder from the instant the circuit was closed for a period of 24 hours.

The pH of the sea water electrolyte was recorded before and after each test to determine the change in the pH during the electrochemical reaction.

The two silver-silver chloride reference electrodes were standardized using a saturated calomel reference electrode.

RESULTS:

The condition of each metal electrode and the pH readings for each cell tested are shown in Table I. The anode potentials, cathode potentials and current density vs. time curves of the bi-metallic cells tested are shown in Figures 3 - 8.

DISCUSSION OF RESULTS:

The pH of the electrolyte showed no significant change during the electrochemical reaction of the various galvanic cells tested.

In Table I a brief statement was made on the condition of each electrode. The clad 7075-T6 aluminum alloy cathode of the galvanic couple, of FS-1H magnesium alloy - Clad 7075-T6, became pitted during the electrochemical reaction in sea water. The corrosive attack of the clad 7075-T6 cathode was attributed to the electrochemical reaction products of the corroding sacrificial anode of FS-1H magnesium alloy. These corrosion products reacted chemically or electrochemically with the clad 7075-T6 aluminum alloy cathode causing the pitting action.

There was no visible evidence of corrosion on the clad 7075-T6 aluminum alloy cathode, when coupled to a sacrificial anode of AA605 aluminum alloy or commercially pure zinc.

**ANALYSIS**

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**PAGE** 3

**REPORT NO.** 56-34

**MODEL**

MGS 56-183

**DATE** 5-2-57

**DISCUSSION OF RESULTS:** (Cont'd.)

The current density of the galvanic couple of FS-1H - clad 7075-T6 was higher than the galvanic couples of XA605 - clad 7075-T6 and commercially pure zinc - clad 7075-T6. (See Figures 3 - 8). The high current density of the FS-1H - clad 7075-T6 couple is the resultant of a greater difference in solution potential between the component electrodes. The current density of this couple with anode-cathode ratio of 1:1 was higher than the same couple with a ratio 1:2. The current density was calculated using a constant cathode area, therefore giving lower values for a smaller cell with the lesser current flow.

The galvanic couple of FS-1H - clad 7075-T6 shows the effect of an active polarization reaction causing a decrease in current flow. This polarization reaction has been caused by a build-up of insoluble corrosion products on the anode and the formation of hydrogen gas at the cathode. Polarization of this type could stifle the flow of current necessary for cathodic protection.

The galvanic couples of XA605 - clad 7075-T6 and commercially pure zinc - clad 7075-T6 have a less active polarization reaction with an increasing current flow. The corrosion products of these two sacrificial anodes are more soluble and migrate away from the anode surface during the electrochemical reaction. In order for a sacrificial cathodic protection system to function successfully the sacrificial material must not become polarized by the formation of a dense film on its surface.

The current density of the galvanic couple of XA605 - clad 7075-T6 decreased when the anode-cathode ratio was varied from 1:1 to 1:2, showing limitation for XA605 as a sacrificial material in this couple. The ratio of the commercially pure zinc - clad 7075-T6 couple was varied in the same manner, but showed no appreciable change in current density. Therefore, commercially pure zinc is believed to be a better sacrificial material for cathodically protecting an aluminum alloy.

One test was conducted at Scripps Institute of Oceanography using a sacrificial anode of commercially pure zinc coupled with a bare 7075-T6 aluminum alloy panel. The commercially pure zinc sacrificial anode was successful in cathodically protecting a bare 7075-T6 panel during 10 days immersion in sea water. The ratio of the commercially pure zinc to the bare 7075-T6 aluminum alloy was 1 to 50. No corrosion was visible on the immersed area of the bare 7075-T6 panel, including the critical area along the waterline. The immersed area of the bare 7075-T6 control was severely corroded after 10 days immersion in sea water.

This program should be continued to develop a workable cathodic protection system for water based aircraft.

**NOTE:** The test data from which this report was prepared are recorded in Engineering Test Laboratories Data Book #971.

TABLE I CONDITION OF ELECTRODES AND THE ELECTROLYTE

EII - I-METHYLIC CELL		ANODE - CATHODE		ZINN OF ELECTROLYTE BEFORE HEATER	
		CONDITION OF ELECTRODES			
ANODE	CATHODE	RATIO			
EII-I MAGNESIUM - CATHOD 7075-T6 AL.		1:1	ANODE - SEVERELY CORRODED CATHODE - GENERAL FITTING OF SURFACE - HITS SYMBOL	8.0	8.1
EII-II MAGNESIUM -		1:2	ANODE - SEVERELY CORRODED CATHODE - GENERAL FITTING OF SURFACE - HITS SMALL FEWER HITS THAN ON SAME ELECTRODE DIMINUTION OF II RATIO	8.1	8.1
CONT'D FEINE ZINC		1:1	ANODE - SLIGHT CORROSION CATHODE - NO VISIBLE CORROSION - SLIGHT FILLY ON ELECTRODE AREA	8.1	8.1
CONT'D FEINE ZINC		1:2	ANODE - SLIGHT CORROSION CATHODE - NO VISIBLE CORROSION - SLIGHT FILLY ON ELECTRODE AREA	8.0	8.1
XH605 ALUMINUM ALLOY		1:1	ANODE - NOVEMENT GENERAL FITTING CATHODE - NO VISIBLE CORROSION - SLIGHT FILM ON ELECTRODE AREA	7.9	7.9
XE605 MANGANESE 10-20% TiO <sub>2</sub> AL.		1:2	ANODE - MEDIUM GRAY CATHODE - -	8.0	8.1
TESTS: Manganese 10-20% TiO <sub>2</sub> AL					
TESTS: Manganese 10-20% TiO <sub>2</sub> AL					

Page 4  
Report No. 56-34

ANALYSIS

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PAGE<sup>5</sup>

REPORT NO. 56-34

MODEL MRS 56-183

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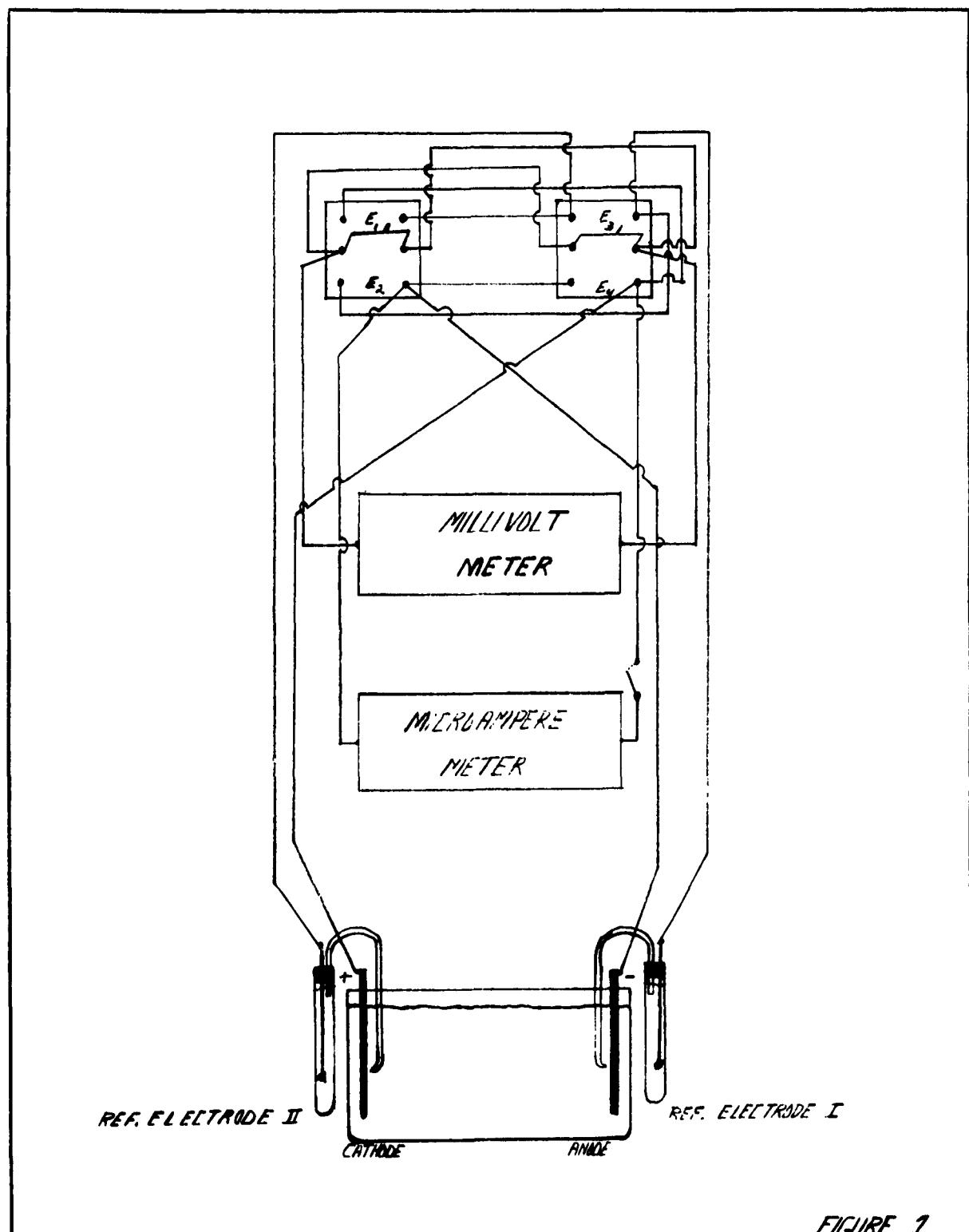


FIGURE 2

ANALYSIS

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PAGE 6  
REPORT NO. 56-34  
MODEL MRS 56-183  
DATE 5-2-57

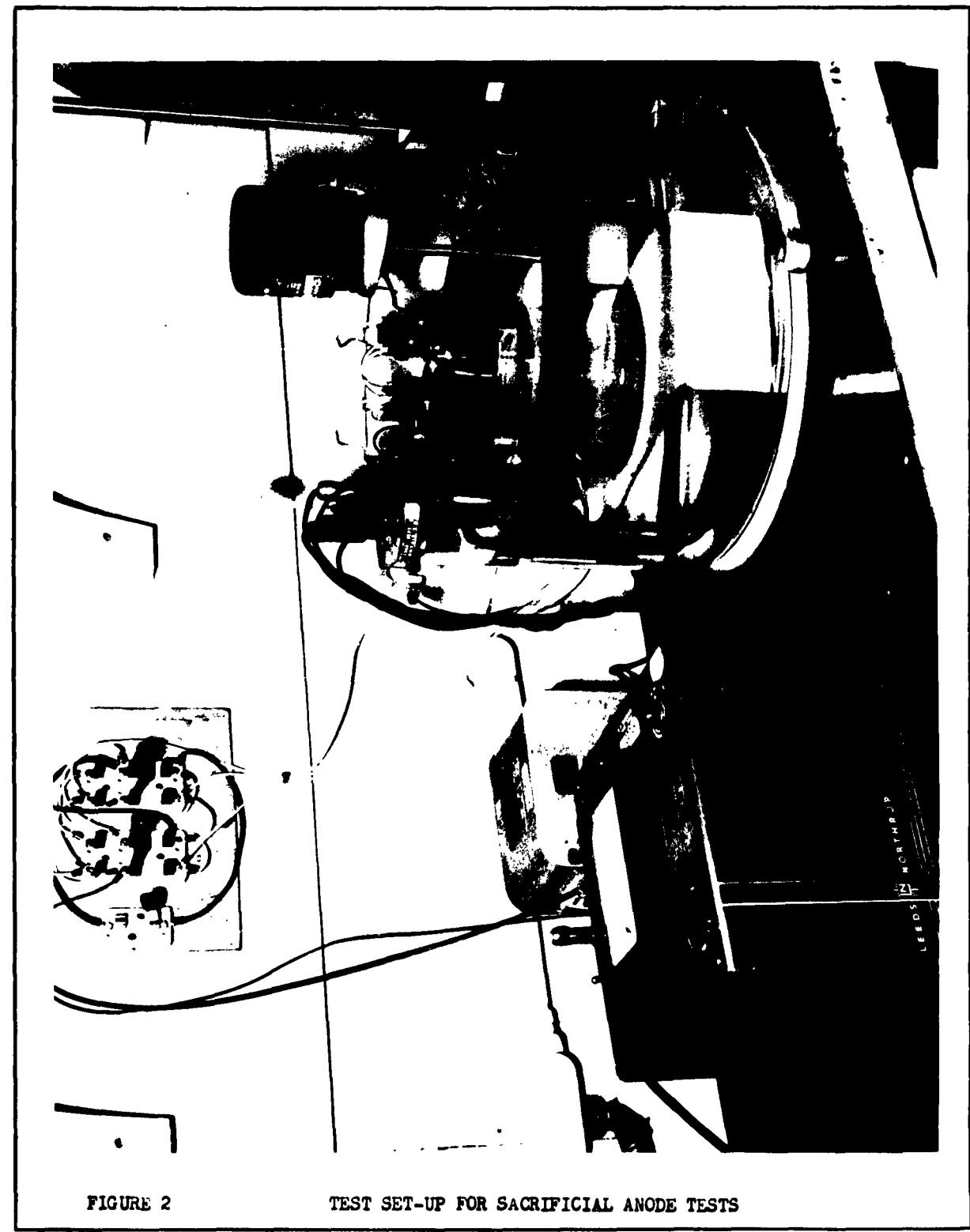
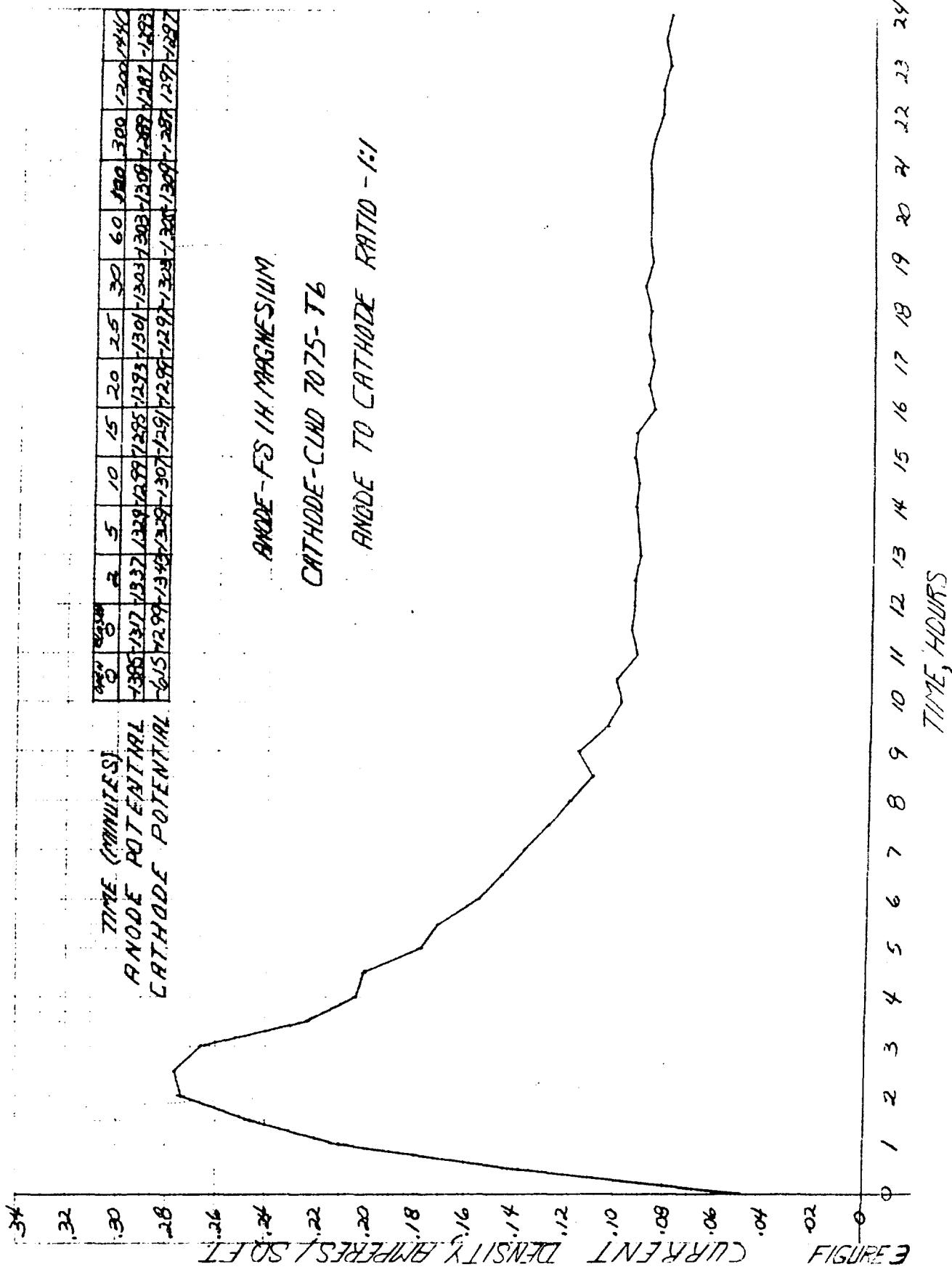
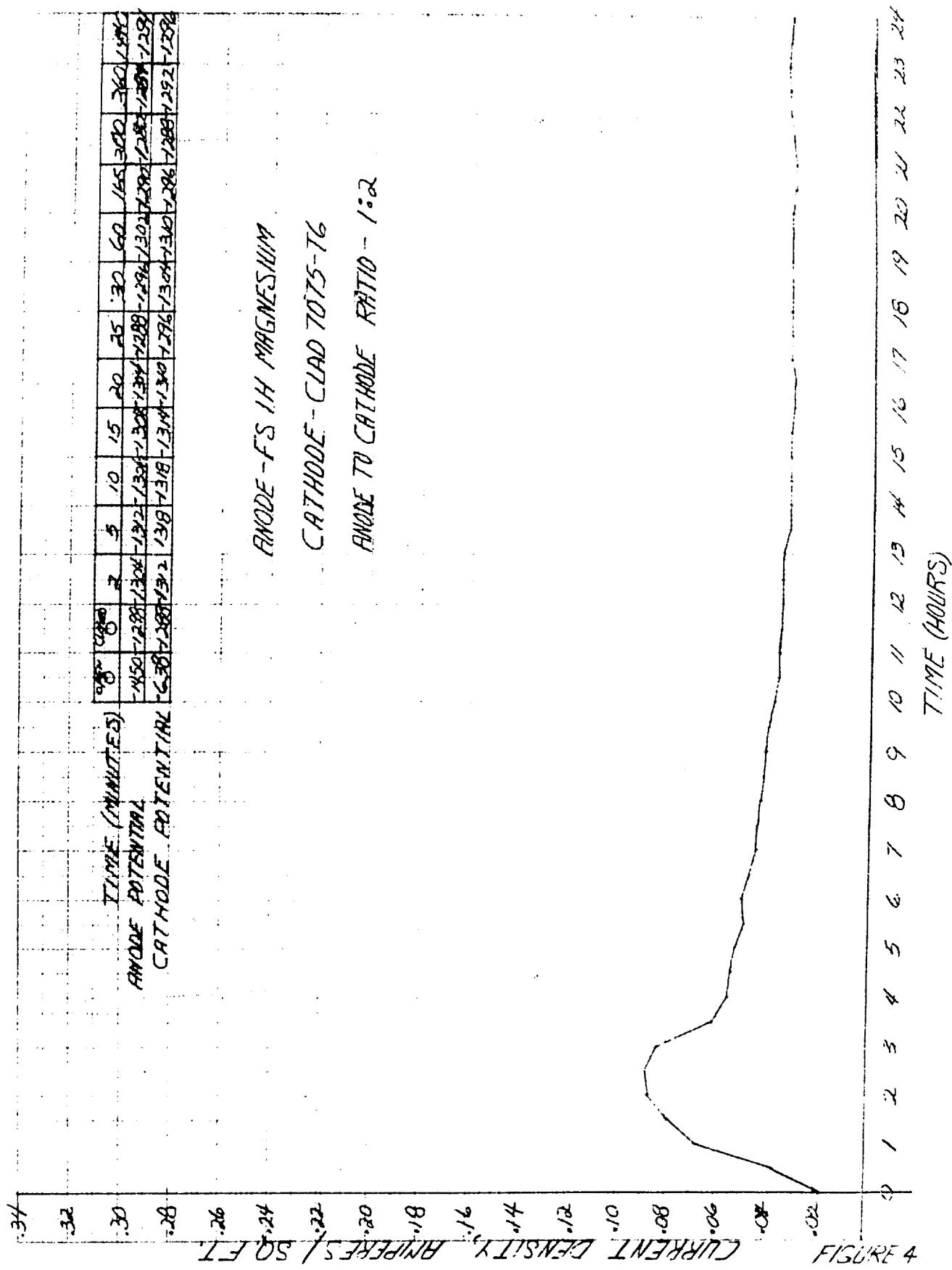
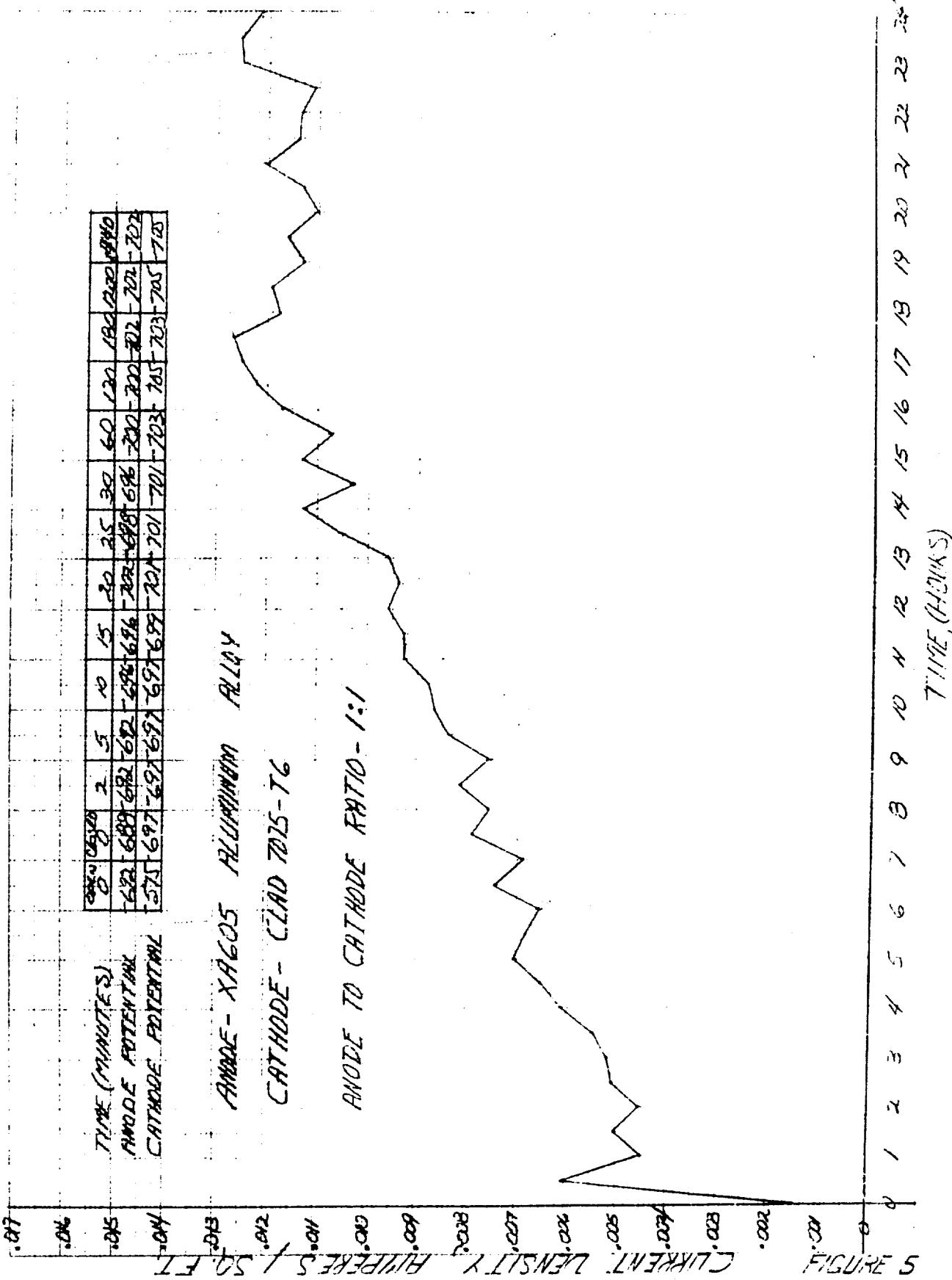


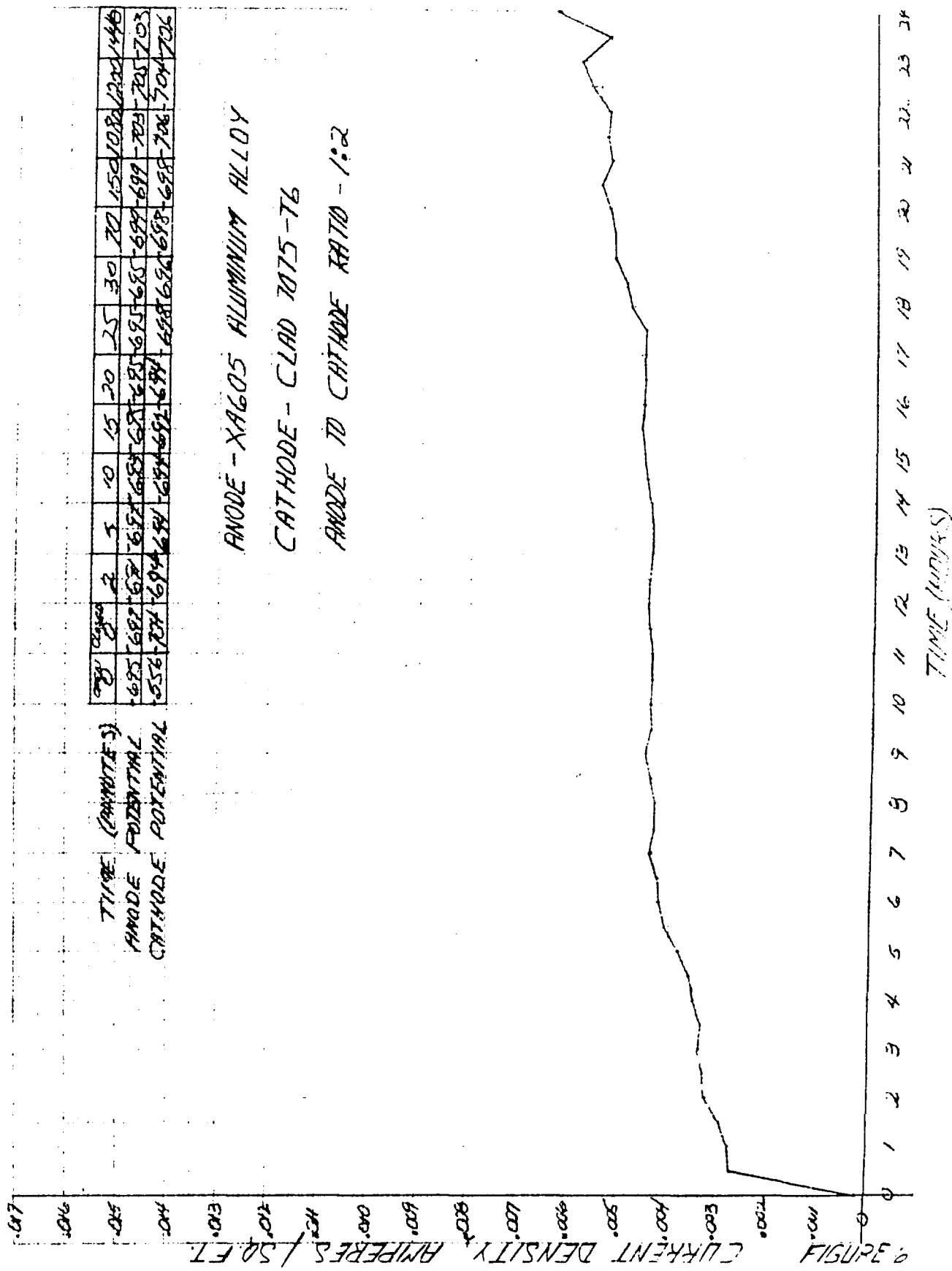
FIGURE 2

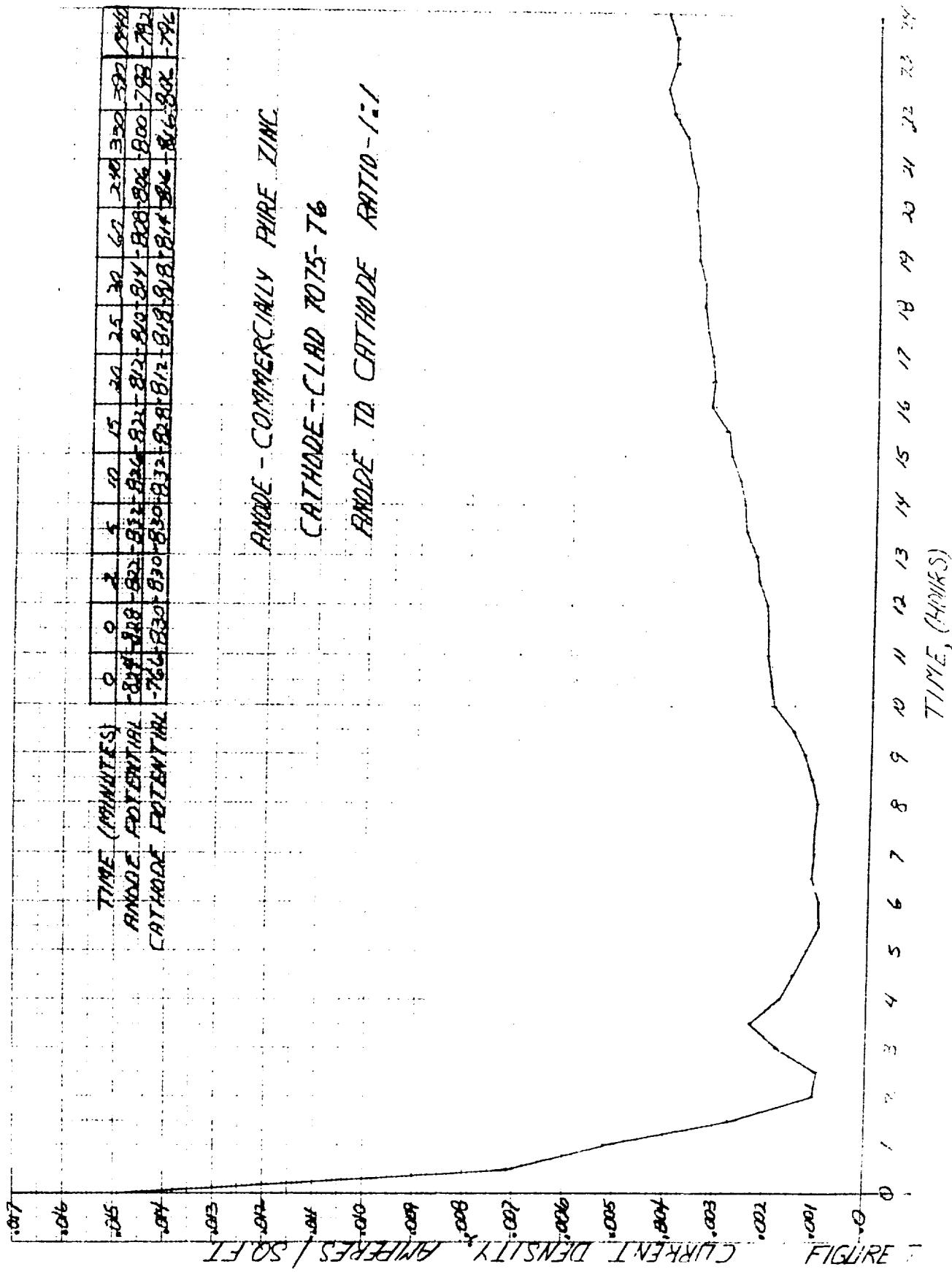
TEST SET-UP FOR SACRIFICIAL ANODE TESTS











TIME (MINUTES)	0	2	5	10	15	20	25	30	40	50	55	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	700	710	720	730	740	750	760	770	780	790	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970	980	990	1000																																																				
RANGE POTENTIAL	-7.56	-7.44	-7.34	-7.24	-7.14	-7.04	-6.94	-6.84	-6.74	-6.64	-6.54	-6.44	-6.34	-6.24	-6.14	-6.04	-5.94	-5.84	-5.74	-5.64	-5.54	-5.44	-5.34	-5.24	-5.14	-5.04	-4.94	-4.84	-4.74	-4.64	-4.54	-4.44	-4.34	-4.24	-4.14	-4.04	-3.94	-3.84	-3.74	-3.64	-3.54	-3.44	-3.34	-3.24	-3.14	-3.04	-2.94	-2.84	-2.74	-2.64	-2.54	-2.44	-2.34	-2.24	-2.14	-2.04	-1.94	-1.84	-1.74	-1.64	-1.54	-1.44	-1.34	-1.24	-1.14	-1.04	-0.94	-0.84	-0.74	-0.64	-0.54	-0.44	-0.34	-0.24	-0.14	-0.04	0.04	0.14	0.24	0.34	0.44	0.54	0.64	0.74	0.84	0.94	1.04	1.14	1.24	1.34	1.44	1.54	1.64	1.74	1.84	1.94	2.04	2.14	2.24	2.34	2.44	2.54	2.64	2.74	2.84	2.94	3.04	3.14	3.24	3.34	3.44	3.54	3.64	3.74	3.84	3.94	4.04	4.14	4.24	4.34	4.44	4.54	4.64	4.74	4.84	4.94	5.04	5.14	5.24	5.34	5.44	5.54	5.64	5.74	5.84	5.94	6.04	6.14	6.24	6.34	6.44	6.54	6.64	6.74	6.84	6.94	7.04	7.14	7.24	7.34	7.44	7.54	7.64	7.74	7.84	7.94	8.04	8.14